

LEVEL SHIFTER HAVING LOW PEAK CURRENT

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BACKGROUND OF THE INVENTION

1. **Field of the Invention**

The present invention relates to a level shifter, and more particularly, to a level shifter used in a Thin Film Transistor Liquid Crystal Display (TFT-LCD) driver.

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2. **Description of Related Art**

A level shifter is a circuit that changes a first low-potential voltage level into a second high-potential voltage level. Typically, several hundred level shifters are included in a TFT-LCD driver. Thus, an increase in peak currents in the level shifters results in an increase in power consumption of the driver. Thus, to decrease the power consumption in the driver, the peak currents in the level shifters need to be reduced.

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FIG. 1 is a circuit diagram of a conventional level shifter used in a TFT-LCD driver. FIG. 2 is a timing diagram illustrating the operation of the conventional level shifter shown in FIG. 1.

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Referring to FIG. 1, the conventional level shifter includes PMOS transistors *MP1* through *MP4*, NMOS transistors *MN1* and *MN2*, and inverters

INV1 through *INV3*. In FIG. 1, *VCC* denotes a first voltage level and *VDD* denotes a second voltage level that has a higher electric potential than the first voltage level *VCC*. *DATA* denotes an input signal whose level changes between the first voltage level *VCC* and a ground voltage level *VSS*.

5 More specifically, when the input signal *DATA* is at the first voltage level *VCC*, the first PMOS transistor *MP1* is turned off and the first NMOS transistor *MN1* is turned on, thus lowering the level of a signal at a first node *N1* to the ground level *VSS*. Also, the first inverter *INV1* makes an inversion signal *DATAB* of the input signal *DATA*, *DATAB* having a logic low level, e.g., the
10 ground level *VSS*, and as a result, the third PMOS transistor *MP3* is turned on and the second NMOS transistor *MN2* is turned off. The fourth PMOS transistor *MP4* is turned on in response to the signal at the first node *N1* having the ground voltage level *VSS*. The level of a signal at a second node *N2* is increased to the second voltage level *VDD*. The second PMOS transistor *MP2* is turned off in
15 response to a signal at the second node *N2*. Therefore, an output signal *OUT* and a complementary output signal *OUTB* reach the second voltage level *VDD* and the ground level *VSS*, respectively.

 When the input signal *DATA* is at the ground voltage level *VSS*, the first PMOS transistor *MP1* is turned on and the first NMOS transistor *MN1* is turned
20 off. The inversion signal *DATAB* of the input signal *DATA* is at a logic high level, e.g., the first voltage level *VCC*, and the third PMOS transistor *MP3* is turned off

and the second NMOS transistor $MN2$ is turned on. The level of the signal at the second node $N2$ is lowered to the ground voltage level VSS and the second PMOS transistor $MP2$ is turned on. The level of the signal at first node $N1$ is raised to the level of the second voltage level VDD . Also, when the level of the signal at first node $N1$ changes, the fourth PMOS transistor $MP4$ is completely turned off. Accordingly, the levels of the output signal OUT and the complementary output signal $OUTB$ reach the ground voltage level VSS and the second voltage level VDD , respectively.

Voltages at the nodes $N1$ and $N2$ of the second and fourth PMOS transistor $MP2$ and $MP4$, which are cross-coupled to each other, overlap at a point before they reach high and low levels, respectively. Thus, undesired overlap current paths are formed among the first and second PMOS transistors $MP1$ and $MP2$ and the first NMOS transistor $MN1$ and among the third and fourth PMOS transistors $MP3$ and $MP4$ and the second NMOS transistor $MN2$. Gates of a fifth PMOS transistor $MP5$ and a fifth NMOS transistor $MN5$, which are included in the second inverter $INV2$, are connected to the second node $N2$. Therefore, the fifth PMOS transistor $MP5$ and the fifth NMOS transistor $MN5$ are affected directly by the overlap current paths, increasing a total peak current.

Accordingly, it is important to minimize the amount of the total peak current generated by level shifters in a display device, such as the TFT-LCD.

SUMMARY OF THE INVENTION

According to an embodiment of the present invention, a level shifter which changes an input signal whose level changes between a first voltage level and a ground voltage level into an output signal whose level changes between a second voltage level and the ground voltage level, the level shifter comprising a first input transistor and a second input transistor which receive the input signal and an inversion signal of the input signal, respectively; a first load transistor and a second load transistor, one side of each transistor being connected to the second voltage level; a first switch transistor connected between the first load transistor and the first input transistor, the first switch transistor responds to the inversion signal; a second switch transistor connected between the second load transistor and the second input transistor, the second switch transistor responds to the input signal; a first output unit that generates the output signal in response to a signal generated at a connection node between the first load transistor and the first switch transistor and a signal at a connection node between the first input transistor and the first switch transistor; and a second output unit that generates a complementary signal of the output signal in response to a signal generated at a connection node between the second load transistor and the second switch transistor and a signal at a connection node between the second input transistor and the second switch transistor.

It is preferable that the first and second input transistors are NMOS transistors, the first and second load transistors are PMOS transistors, and the first and second switch transistors are PMOS transistors.

It is preferable that the first output unit comprises a PMOS transistor and
5 an NMOS transistor connected in serial between the second voltage level and the ground voltage level, wherein a signal generated at the connection node between the first load transistor and the first switch transistor is applied to a gate of the PMOS transistor, a signal generated at the connection node between the first input transistor and the first switch transistor is applied to a gate of the
10 NMOS transistor, and the output signal is output from a connection node between the PMOS transistor and the NMOS transistor.

It is preferable that the second output unit comprises a PMOS transistor and an NMOS transistor connected in serial between the second voltage level and the ground voltage level, wherein a signal generated at a connection node
15 between the second load transistor and the second switch transistor is applied to a gate of the PMOS transistor, and a signal at a connection node between the second input transistor and the second switch transistor is applied to a gate of the NMOS transistor, the complementary signal of the output signal is output from a connection node between the PMOS transistor and the NMOS transistor.

20 According to an embodiment of the present invention, a level shifter for changing an input signal whose level changes between a first voltage level and a

ground voltage level into an output signal whose level changes between a second voltage level and the ground voltage level, the level shifter comprises first through fourth nodes. The level shifter comprises a first PMOS transistor comprising a source, a drain, and a gate connected to the second voltage level, the first node, and the fourth node, respectively, and a second PMOS transistor comprising a source, a drain, and a gate connected to the first node, the second node, and an inversion signal of the input signal, respectively. The level shifter further comprises a first NMOS transistor comprising a drain, a source, and a gate connected to the second node, the ground voltage level, and the input signal, respectively, a third PMOS transistor comprising a source, a drain, and a gate connected to the second voltage level, the third node, and the second node, respectively, and a fourth PMOS transistor comprising a source, a drain, and a gate connected to the third node, the fourth node, and the input signal, respectively. The level shifter comprises a second NMOS transistor comprising a drain, a source, and a gate connected to the fourth node, the ground voltage level, and the inversion signal of the input signal, respectively, and a fifth PMOS transistor comprising a source, a gate, and a drain connected to the second voltage level, the first node, and an output node, respectively. The level shifter further comprises a third NMOS transistor comprising a drain, a gate, and a source connected to the output node, the second node, and the ground voltage level, respectively, a sixth PMOS transistor comprising a source, a gate, and a

drain connected to the second voltage level, the third node, and a complementary output node, respectively, and a fourth NMOS transistor comprising a drain, a gate, and a source connected to the complementary output node, the fourth node, and the ground voltage level, respectively.

5 The level shifter further comprises an inverter for using the first voltage level as a power source, inverting the input signal, and outputting the inversion signal of the input signal.

BRIEF DESCRIPTION OF THE DRAWINGS

10 The present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a circuit diagram of a conventional level shifter used in a thin film transistor liquid crystal display (TFT-LCD) driver;

15 FIG. 2 is a timing diagram illustrating the operation of the conventional level shifter shown in FIG. 1;

FIG. 3 is a circuit diagram of a level shifter used in a TFT-LCD driver, according to a preferred embodiment of the present invention; and

FIG. 4 is a timing diagram illustrating the operation of the level shifter shown in FIG. 3, according to an embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings. The same reference numerals represent the same elements throughout the drawings.

5 FIG. 3 is a circuit diagram of a level shifter used in a thin film transistor liquid crystal display (TFT-LCD) driver, according to a preferred embodiment of the present invention. Referring to FIG. 3, the level shifter includes a first input transistor *MN1*, a second input transistor *MN2*, a first load transistor *MP1*, a second load transistor *MP3*, a first switch transistor *MP2*, a second switch transistor *MP4*, a first output unit 31, a second output unit 33, and an inverter *INV1*.

Here, the first and second input transistors *MN1* and *MN2* are NMOS transistors, and the first and second load transistors *MP1* and *MP3* and the first and second switch transistors *MP2* and *MP4* are PMOS transistors. *VCC* denotes a first voltage level and *VDD* denotes a second voltage level that has a higher electric potential than the first voltage level *VCC*.

An input signal *DATA* is a signal whose level changes between the first voltage level *VCC* and a ground level *VSS*. The inverter *INV1* uses the first voltage level *VCC* as a power source, inverts the input signal *DATA*, and outputs an inversion signal *DATAB*.

A source, drain, and gate of the PMOS transistor *MP1*, which is the first load transistor, are connected to the second voltage level *VDD*, a first node *N1*, and a fourth node *N4*, respectively. A source, drain, and gate of the PMOS transistor *MP3*, which is the second load transistor, are connected to the second voltage level *VDD*, a third node *N3*, and a second node *N2*, respectively.

A source and drain of the PMOS transistor *MP2*, which is the first switch transistor, are connected to the first node *N1* and the second node *N2*, respectively, and the inversion signal *DATAB* of the input signal *DATA* is input to a gate of the PMOS transistor *MP2*. A source, drain, and gate of the PMOS transistor *MP4*, which is the second switch transistor, are connected to the third node *N3*, a fourth node *N4*, and the input signal *DATA*, respectively.

A drain, source, and gate of the NMOS transistor *MN1*, which is the first input transistor, are connected to the second node *N2*, the ground voltage level *VSS*, and the inversion signal *DATAB*, respectively.

The first output unit 31 outputs an output signal *OUT* in response to signals generated at the first and second nodes *N1* and *N2*. The second output unit 33 outputs a complementary output signal *OUTB* in response to signals at the third and fourth nodes *N3* and *N4*.

More specifically, the first output unit 31 includes a PMOS transistor *MP5* and an NMOS transistor *MN5*. A source, gate, and drain of the PMOS transistor *MP5* are connected to the second voltage level *VDD*, the first node *N1*, and an

output node from which the output signal *OUT* is output, respectively. A drain, gate, and source of the NMOS transistor *MN5* are connected to the output node, the second node *N2*, and the ground voltage level *VSS*, respectively.

The second output unit 33 includes a PMOS transistor *MP6* and an NMOS transistor *MN6*. A source, gate, and drain of the PMOS transistor *MP6* are connected to the second voltage level *VDD*, the third node *N3*, and a complementary output node from which the complementary output signal *OUTB* is output, respectively. A drain, gate, and source of the NMOS transistor *MN6* are connected to the complementary output node, the fourth node *N4*, and the ground voltage level *VSS*, respectively.

FIG. 4 is a timing diagram illustrating the operation of the level shifter shown in FIG. 3, according to an embodiment of the present invention.

Hereinafter, the operation of the level shifter shown in FIG. 3 will be described with reference to the timing diagram of FIG. 4. First, when the input signal *DATA* is at a logic high level, e.g., the first voltage level *VCC*, the PMOS transistor *MP1* is turned on and the NMOS transistor *MN2* is turned off. The level of the second node *N2* is lowered to the ground voltage level *VSS*, and the PMOS transistor *MP3* is turned on, thus raising the level of the third node *N3* to the second voltage level *VDD*.

The input signal *DATA* is at the first voltage level *VCC*, and a voltage *Vgs* between a gate and source of the PMOS transistor *MP4* is a level *VCC-VDD*.

The PMOS transistor $MP4$ is turned on and the level of the fourth node $N4$ is raised to the second voltage level VDD .

The PMOS transistor $MP1$ falls within a cut-off zone because the level of the fourth node $N4$ is at the second voltage level VDD , and a logic low level, e.g.,

5 the ground voltage level VSS , is applied to the gate of the PMOS transistor $MP2$.

Thus, the PMOS transistor $MP2$ reaches a saturation zone, and the voltage level of the first node $N1$ reaches a level $V_{thp2}+V$. Here, V_{thp2} denotes a threshold

voltage of the PMOS transistor $MP2$, the voltage level of the threshold voltage V_{thp2} being higher than that of a threshold voltage V_{thp2} of the PMOS transistor

10 $MLP1$. V denotes a minimum voltage needed to saturate the PMOS transistor

$MP2$. When the voltage level of the first node $N1$ reaches the level $V_{thp2}+V$, the

PMOS transistor $MP2$ operates like a resistor and makes the first and second

nodes $N1$ and $N2$ have different voltage levels, thereby preventing formation of

an overlap current path. As a result, peak current and average current

15 decrease.

A voltage level difference V_{gs} between V_{gs} between the gate and source of the PMOS transistor $MP5$ is a level $V_{thp2}+V-VDD$ that is needed to turn on the

PMOS transistor $MP5$. In this case, the output signal OUT is at the second voltage level VDD and the NMOS transistor $MN5$ is turned off according to the

20 voltage level of the second node $N2$. The PMOS transistor $MP6$ is turned off

according to the voltage level of the third node $N3$ and the NMOS transistor $MN6$

is turned on according to the voltage level of the fourth node *N4*. Thus, the complementary output signal *OUTB* is at the ground voltage level *VSS*.

Accordingly, in a level shifter according to an embodiment of the present invention, an input to the gate of the PMOS transistor *MP5* and an input to the gate of the NMOS transistor *MN5* can be separated from each other by the PMOS transistor *MP2* acting as a resistor, and an input to the gate of the PMOS transistor *MP6* and an input to the gate of the NMOS transistor *MN6* can be separated from each other by the PMOS transistor *MP4* acting as a resistor, thereby reducing an overlap current. As a result, a peak current decreases. The PMOS transistor *MP5* and the NMOS transistor *MN5*, and the PMOS transistor *MP6* and the NMOS transistor *MN6* operate with time intervals, thereby reducing overlap current and peak current.

When the input signal *DATA* is at a logic low level, e.g., the ground voltage level *VSS*, the NMOS transistor *MN2* is turned on and the level of the fourth node *N4* is lowered to the ground voltage level *VSS*. The fourth node *N4* is connected to the gate of the PMOS transistor *MP1*, the PMOS transistor *MP1* is turned on, and a voltage level difference *V_{gs}* between the gate and source of the PMOS transistor *MP2* is *VCC-VDD*. Thus, the PMOS transistor *MP2* is turned on and operates as a switch. Therefore, the second node *N2* is at the second voltage level *VDD*. The NMOS transistor *MN1* is turned off, the PMOS transistor *MP4* reaches a saturation level, and the third node *N3* has an electric

potential of $V_{thp4}+V$. As a result, the PMOS transistor *MP6* is turned on and the complementary output signal *OUTB* is at the second voltage level *VDD*. The NMOS transistor *MN6* is turned off according to the voltage level of the fourth node *N4*. Also, the PMOS transistor *MP5* is turned off the voltage level of the first node *N1* and the NMOS transistor *MN5* is turned on according to the voltage level of the second node *N2*, thus lowering the level of the output signal *OUT* to the ground voltage level *VSS*.

While this invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.